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New England District

Elizabeth Mine Site Summary Report

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Executive Summary

This Site Summary Report (SSR) has been prepared by Arthur D. Little, Inc., for the U.S. Army Corps of Engineers (USACE) – New England District. The SSR was developed to provide a brief summary of the historical and environmental information relating to the Elizabeth Mine Site in South Strafford, Vermont. The SSR was not intended to be a comprehensive evaluation of the Site. Future document such as the Remedial Investigation Work Plan, Remedial Investigation Reports, and Engineering Evaluation and Cost Analysis would contain a more rigorous evaluation of site conditions.

This report summarizes the Mine's history and operations, compiles and reviews data previously collected at the Site, and describes the current setting. The Site Summary Report also identifies potential data gaps that may need to be addressed as part of the expected remedial investigation and feasibility study (RI/FS). Some of the information relating to the data gaps would also be necessary to complete the design of a non-time-critical removal action (NTCRA). The purpose of U.S. Environmental Protection Agency (EPA) and USACE activities at the Site from January 2000 to September 2000 was to: assess existing data and studies; collect additional data to address citizen concerns regarding the magnitude of the environmental impacts; and to provide information that would enable EPA to initiate the RI/FS and possibly a NTCRA once the Community Advisory Group (CAG) and the State of Vermont support the National Priorities List (NPL) listing of the Site. If EPA were to initiate the planning activities in support of a NTCRA, the data collected during 2000 would also support the engineering assessment of cleanup options, and the identification and evaluation of the most appropriate cleanup options.

The Elizabeth Mine is an abandoned copper mine, which was discovered in 1793 and used as a source of iron and iron sulfate. Copper production began in approximately 1830. Over the next 100 years, several smelters were built, and approximately 5,250 tons of copper were removed from the mine. In 1943, the mine was reopened to provide copper for World War II, and was operated until 1958. Between 1943 and 1958, the mine yielded 2,967,000 tons of ore, resulting in production of approximately 50,460 tons of copper (Howard, 1969). In addition, between 1810 and circa 1880, the upper part of the Site was used to produce copperas. The Site has now been divided into approximately twelve private properties. Still evident at the Site are three tailings piles, two mine cuts, an air shaft and vent, several deteriorating buildings, and stone foundations from early production buildings and dwellings.

Past reports indicate that the Elizabeth Mine is a source of acidic leachate, metals, and silt to Copperas Brook and, subsequently, to the West Branch of the Ompompanoosuc River below its confluence with Copperas Brook. Effects in the West Branch are observed at least 600 meters below the confluence of the West Branch and Copperas Brook, and possibly further. Metals such as iron, aluminum, manganese, copper, nickel, and zinc have been found at concentrations in excess of EPA and Vermont reference criteria set to protect sensitive aquatic life. Although some portion of these downstream metals concentrations may be attributable to natural background (geologic) conditions, some studies have concluded that the mine is a significant contributor to the metals concentrations in the West Branch below the confluence with Copperas Brook. Naturally high alkalinity in these waters may have a beneficial effect on the bioavailability of some metals.

A review of the surface water data generated through previous studies indicates that the samples have not been collected at consistent locations, and sampling events occurred during a variety of seasons and under a variety of surface water flow conditions. This variability is likely to have an impact on the comparability of metals results. Thus, this report concludes that the past surface water data contain gaps and, although these data may be used for preliminary comparison purposes, they cannot provide a full understanding of the Site's surface water quality.

Similarly, sediment data collected previously are variable with respect to location and timing. Biota in the surface waters surrounding the Site have been studied, as has biological community composition. Abundance and diversity are reportedly affected, however, further delineation of the extent of damage and of the remaining communities is necessary. Ground water data were collected at seeps and at the flooded air shaft; no deeper ground water data are available. Tailings piles have been sampled, and this data may be used in the future as a starting point for characterizing the tailings piles. However, the sampling was limited and may be considered representative of smaller areas of the Mine.

1.0 Introduction

This Site Summary Report (SSR) has been prepared by Arthur D. Little, Inc., for the United States Army Corps of Engineers – New England District. The SSR was developed to provide a brief summary of the historical and environmental information relating to the Elizabeth Mine Site in South Strafford, Vermont. The SSR was not intended to be a comprehensive evaluation of the Site. Future document such as the Remedial Investigation Work Plan, Remedial Investigation Reports, and Engineering Evaluation and Cost Analysis would contain a more rigorous evaluation of site conditions.

Historical documents were provided by the USACE, EPA, the Strafford Historical Society, and other local sources. The environmental data were compiled from past site investigation reports. These reports were used to determine the extent to which environmental contamination has been characterized. The data were also reviewed to determine usability for future USACE studies and reports. A compendium of historical and environmental reports has been prepared and made available to the public.

The Elizabeth Copper Mine (Elizabeth Mine) is an abandoned copper mine which also produced copperas (iron sulfate). Massive sulfide ores were first discovered in 1793 in an outcrop near the crest of Copperas Hill. Intermittent mining occurred at this property over a 148 year period, beginning in 1810 and ending in 1958.

From 1810 to about 1880, ore was mined and copperas was manufactured on the upper part of the Site, where the northern-most open cut and Tailings Pile 3 are located. Copper production began in about 1830, with ore from the same mine cuts being smelted in furnaces located beside the West Branch of the Ompompanoosuc River. Over the next 100 years, several smelters were built at various locations on the Site, chiefly on the eastern slope of Copperas Hill. They operated intermittently and produced an estimated 5,250 tons of copper from the extracted sulfide ore.

In 1942, the mine was reopened to provide copper for World War II, and was operated until 1958. Between 1943 and 1958, the mine yielded 2,967,000 tons of ore, resulting in production of approximately 50,460 tons of copper (Howard, 1969).

The Site is currently divided into approximately twelve private properties (Figure 1). Still evident at the Site are three tailings piles, two open mine cuts, an air vent, a ventilation shaft, a number of deteriorating buildings, and stone foundations from early production buildings and residences. As the cultural resources program for the Site continues, more detail regarding the structural condition of the buildings will be obtained.

The tailings piles are a combination of roasted ore waste and fines from the copper extraction process. The piles have been designated Tailings Pile 1 (TP1), Tailings Pile 2 (TP2), and Tailings Pile 3 (TP3) and this report will continue to use that convention. TP1 and TP2 cover approximately 32 and 5 acres, respectively, and result from the most recent operations of the 1940’s and 1950’s. TP3 results from earlier (1810 to 1880) copperas-producing operations and covers about 6 acres

Past reports indicate that the Elizabeth Mine is a source of acidic aqueous leachate, metals, and suspended solids to Copperas Brook and the West Branch of the Ompompanoosuc River, below its confluence with Copperas Brook. Past and current data indicate that the West Branch is affected from the confluence to a distance of at least 600 meters below the confluence, where complete mixing appears to occur. Fish abundance and other biological indicator species have been impacted in this portion of the Ompompanoosuc River. Recent EPA activity at the Site is due to a request by the Vermont Agency of Natural Resources (VTANR) that EPA consider initiating cleanup of the Site under the Superfund removal authority. EPA has proposed a dual track approach to the public that would involve an initial NTCRA that is implemented simultaneously with the RI/FS. The EPA determined that a NTCRA is currently the best of the removal approaches to control potential major source areas from the Elizabeth Mine that contribute to surface water contamination, while providing an opportunity to address historic preservation issues and community involvement. The purpose of EPA and USACE activities at the Site from January 2000 to September 2000 was to: assess existing data and studies; collect additional data to address citizen concerns regarding the magnitude of the environmental impacts; and to provide information that would enable EPA to initiate the RI/FS and possibly a NTCRA once the CAG and State of Vermont support the NPL listing of the Site. If EPA were to initiate planning activities in support of a NTCRA, the data collected during 2000 would also support the engineering assessment of cleanup options, and would help to identify and evaluate the most appropriate cleanup options.

2.0 Site History

The Elizabeth Mine Site history is summarized in this section as a brief overview to provide the background information about the Site. Historical documents examined as part of this review include scientific journal articles, newspaper articles, government reports, and other publications. Many detailed geological investigations are also available in the literature.

For the purposes of this report, the operations at the Elizabeth Mine are divided into three general periods. The ore body was reportedly discovered in 1793, and thought to be a good source of iron ore, although no significant iron production is known to have occurred. Copperas production was not initiated for at least 17 years following the discovery. The first operational period covers 1810 to 1870, when a copperas-producing operation was located at the upper part of the Elizabeth Mine Site near the current TP3. The second period began in 1830, when copper mining/processing started, and lasted approximately 100 years. The third and final period of operations was from 1943 to 1958, in response to the need for copper during World War II. These time periods, operations, and a list of the major owners are summarized in Table 1 (tables may be found at the end of the text). It should be noted, however, that operations varied during each time period, for example, when new processes or improvements in technology were implemented. A more detailed outline of the Site history may be found in Appendix A.

Each period of operation is described below with respect to the operators, the tonnage produced, and the type of operations conducted. Where information is available, the areas of the Site used and the buildings constructed are described.

1793 – 1810

The period from discovery to 1810 focused on evaluating the property as an iron ore resource. High sulfur content in the ore material made the extraction of iron difficult and uneconomical, given technologies available at the time. As such, this period is not considered a mining period.

Period I
1810 – 1880, Large-Scale Copperas Production

Copperas is an iron sulfate which was used for dye and ink manufacturing, treating timber, and as a disinfectant. From 1824 to 1833, annual production averaged 750 tons, reaching a maximum output of 1,500 tons in 1833. Copperas produced at the Elizabeth Mine during this period was regarded as a key and strategic resource. The only raw materials used were the ore and wood from the surrounding forests. Since the methods of copperas production changed over the decades of operation, it may be difficult to distinguish the details of each separate operation during this period (Smith, 2000).

The sulfide mineral pyrrhotite (FeS) was mined from an open cut at the top of Copperas Hill, and the extraction processes took advantage of the natural steep slope of the adjacent ground. After the ore was blasted out of the ground, usually using gunpowder, it was broken into pieces with sledgehammers, then wheeled to the TP3 area by handcars. It was formed into conical heaps on the "leaching ground," which exists today as TP3. A smothered combustion, started either spontaneously or by wood fuel, was sustained and controlled by spraying with water (Adams, 1845). The ore was "roasted" in this fashion to oxidize and decompose the sulfide minerals, releasing iron sulfate. A heap would, if properly burned, be thoroughly decomposed and ready for leaching over a number of months. Overheating was prevented by applying a stream of water at frequent intervals. When overheated, the iron in the ore would be melted and run into large solid masses and the sulfur would be driven into the atmosphere as sulfurous acid gas (Duncan, 1871).

After the burning was complete, water was passed through the oxidized material, generating a copperas "liquor." The liquor accumulated in small holding ponds (reservoirs) (Thompson, 1842). Below the reservoirs on the hillside, evaporators received the liquor via troughs and small streams from the reservoirs. In the earliest operations, the liquor was passed through several tiers of brush in the evaporator buildings to facilitate the process of evaporation (Hitchcock et al., 1867). The water was then conveyed to lead-lined vats, where the liquor was boiled. After reaching the desired acidity, it was transferred to the crystallizers, where the copperas continued to crystallize while cooling. When the crystallization ceased after about 8 to 10 days, the water was again returned to the boilers, and the crust of copperas was removed and drained (Thompson, 1824). The heavy crust on the sides and bottoms of the crystallizers was frequently 5 inches thick (Duncan, 1871). After crystallization, the copperas was shoveled into the packing rooms. When dry, it was put into casks holding about half a ton each (Thompson, 1842). The crystallizers were housed near the road in two large factory buildings. The dimensions of these buildings varied over the years from 180 feet by 46 feet (report of 1824) to 267 feet by 94 feet (1842), later reduced to 110 feet by 25 feet (1870) (Smith, 2000). Remnants of these structures and the equipment used during this period can be observed today.

Period II
1830 – 1930, Early Copper Production

Mining operations were carried out on an intermittent basis during this time period. Several smelters were built and an estimated 250,000 tons of ore were mined, yielding approximately 5,250 tons of copper.

The first smelter was built in 1830 along the Ompompanoosuc River in an area referred to as Furnace Flat, or Copper Flat. A number of copper smelters were built on the Site. Isaac Tyson, Jr. alone is thought to have built and operated as many as 6 furnaces around the mine, until leaving in 1834. Smelting reportedly continued until around 1837, at which time technical, transportation, and financial problems halted operations .

Production resumed intermittently after that time, and was active during the Civil War. In the late 1870s, Isaac Tyson's son James inherited the copper mine and named it after James' wife Elizabeth. Tyson's company, Elizabeth Mining Company, went into receivership in May 1904, at which point the property was leased to Judson and Rowand.

Prior to 1886, when Tyson's 160-foot vertical shaft was completed at the top of Copperas Hill, most of the ore was mined from the northern (original) open cut, with some underground production. In 1899, a crosscut adit measuring 1,340 feet in length was finished, opening up the ore body 225 feet (vertically) below the original outcrop (Weed, 1903). This adit served as a main access to the ore body until the end of operations in 1958.

In 1908, a businessman from New Jersey, August Heckscher, completed a project that included elaborate new equipment, along with a new hydroelectric plant at the Town of Sharon. The structures built included a mill, magnetic separators, a furnace, trestle tramways, a 400-foot brick flue to trap dust, and a 125-foot chimney to carry off smelter fumes. However, an explosion in the furnace building ended the project, and even though it was rebuilt, it never went into successful operation (Blaisdell, 1970). During the years from 1910 to 1916, the mine was idle. In 1916, a new smelter was constructed, but operations were discontinued in the same year due to technical problems. In 1917, a 100-ton flotation plant (upgraded soon after to 200 tons) was constructed, and during 1918 produced 300,000 pounds of copper concentrate. The flotation process, similar to technologies used today, was used to segregate copper sulfide in a fluid "froth." The plant closed down in May 1919, following a drop in metal prices. In 1925, the American Metal Company leased the mine, and mined 20,000 tons of ore, producing 1,756 tons of 18 percent concentrate during six months of operation. A remodeled mill was started in April 1929 by the National Copper Corporation, which produced 80 tons of copper per month. This company was shut down during the depression in June, 1930 (Howard, 1969).

The property and surrounding areas are shown on Figure 2. Figure 3 shows the topography of the Elizabeth Mine area in 1890, superimposed on a current aerial photograph of the Site. This figure roughly illustrates the topography prior to the final mining period, 1943 to 1958, when TP1 and TP2 were formed.

Period III
1943 – 1958, World War II Era Copper Production

In response to the need for copper during World War II, the Vermont Copper Company reopened the mine in 1942 and provided all final product to the U.S. government. In 1954, the mine was sold to Appalachian Sulfides, Inc., a subsidiary of the Nipissing Mines Company Limited of Canada. From 1942 to 1958, a total of 2,967,000 tons of ore were mined, from which 91% of the copper was recovered and processed into concentrate, yielding approximately 50,460 tons of copper metal. The mill averaged

800 tons of ore per day, and could handle peak production of 1,100 tons per day (Howard, 1969).

During this period, copper was produced as a 25 percent concentrate, greenish-brown powder, which was shipped to Long Island for smelting. A small amount of gold was also recovered from this process. In 1951, sulfur was produced from reworking the pyrrhotite-rich tailings to meet demands during a national sulfur shortage. The mill was enlarged, and about a third of the tailings were reworked to salvage the pyrrhotite for shipping to a paper manufacturer. In the early 1950s, the employment level reached its peak at nearly 250 persons; peak annual production was 4,250 tons of copper (Blaisdell, 1970). Residential housing for forty families, along with a recreation center, were constructed on-site in 1943 by the Federal Housing Authority (Jacobs, 1944).

During this period, mine activities included blasting the ore, then crushing and grinding it into a fine powder, which was combined in the flotation process with a mixture of water, pine oil, and chemicals. The copper-rich granules were attracted to the oily bubbles of this liquid, while waste material sank to the bottom and was removed as tailings. (Blaisdell, 1970). The tailing slurry was carried by open troughs to two tailings ponds, where the solids were settled. These processes gradually filled the valley below the mill, and resulted in the formation of two of the three major areas of tailings, TP1 and TP2 (USACE, 1989).

Copperas Brook was diverted into a concrete pipe (which became covered with tailings) to control surface water flow during this active period. A system of decant towers and drains was built into TP1 and TP2 to dewater the tailings slurried into the valley. The drainage system consists of 3-foot-diameter, vertical concrete conduits with grated inlets on top and 2-foot-diameter concrete pipes. During mining operations, the tailings were deposited in a hydraulic slurry in the valley, the fines settled out to form the tailing pile, and the water spilled into the decant conduit, and was carried by the buried piping to the base of the tailings pile at the easterly corner of TP1 (USACE, 1989). Erosion has undermined and subsequently destroyed the drain system of TP2. Copperas Brook now flows directly into TP1, forming a pond that drains by percolation through the tailings and by discharge to the decant tower on the northwest side of the pond. Erosion has occurred around this decant tower, creating a hole in the tailings. Percolation through the tailings pile and through the old drainage system exits at the base of TP1 and forms a fan-shaped delta (USACE, 1989).

3.0 Site Investigations

This section summarizes relevant environmental data from current and past Elizabeth Mine Site investigations for the following site features: surface water, sediments, tailings, soils, ground water, and biota. Table 2 provides a list of environmental investigations in order of publication, with brief descriptions of the scope and findings of each study. For each site feature, the data gaps and usability of the available data are summarized in this section, and are discussed in Section 5.0. Past investigations reflecting the current knowledge of the area's hydrology and geochemistry are summarized in Section 4.0. Although it is likely that data gaps exist with regard to the area's hydrology and geochemistry, further data needs with respect to these site features (for example, data associated with the stability of the tailings piles or ground water flow) will be discussed in the RI Work Plan and may also be addressed in documents prepared in support of a NTCRA.

An assessment of the quality and usability of the data collected prior to EPA involvement has not been performed, therefore, this data must be considered qualitative until further evaluation of the data quality has been completed. Each study described below may also have design or data shortcomings and associated uncertainties. However, all available data was used in this assessment to provide an objective representation of the cumulative findings of all studies to date. As a result the preliminary conclusions presented in the SSR may be modified as additional data is gathered at the Site. While a precise interpretation of the environmental impacts at the Site must await additional data gathering and evaluation, general statements about the impact of the Site on the environment are present in the SSR.

3.1 Surface Water

Dissolved metals, including but not limited to copper, cadmium, iron, mercury, and zinc, occur in Copperas Brook and the West Branch of the Ompompanoosuc River after the confluence with Copperas Brook until the end of the mixing zone, and have frequently been found in excess of applicable chronic surface water criteria set to protect sensitive aquatic life. These criteria include the EPA Ambient Water Quality Criteria (AWQC) for freshwater and the Vermont Class B water criteria. In addition, manganese is compared to an EPA ecotoxicity threshold value developed by the Great Lakes Water Quality program in 1996 The criteria are applied to all sampled surface water on and surrounding the Elizabeth Mine Site, as described below. Although some portion of these metals concentrations in the West Branch after the confluence with Copperas Brook may be attributable to background, or naturally occurring metals in Vermont surface waters, several authors have concluded that the mine is a significant contributor to the metals concentrations in this area of the West Branch. We have summarized data from current and previous surface water studies to provide a general overview of the contaminants historically found in surface waters (see Appendix C). All metals data and criteria have been hardness adjusted in order to take into account the existing alkalinity and pH conditions of the surface water bodies under study.

Historical data for the West Branch and East Branch of the Ompompanoosuc are included in Appendix C. An assessment of the quality and usability of the data collected prior to EPA involvement has not been performed, therefore, this data must be considered qualitative until further evaluation of the data quality has been completed.

The past surface water studies reviewed include:

- The Vermont Agency of Environmental Conservation (VTAEC, 1977) sampled 10 locations spaced above, around, and below TP1, as well as on the Ompompanoosuc River in October and November of 1977 for analysis of 10 metals. A conventional numbering system was used to name the sampling locations (1-10).

- The Elizabeth Mine Study Group (EMSG, 1999), along with Step by Step, Inc. and Damariscotta, sampled three surface water locations for a core group of metals and pH. The locations were:
  - H1 Drainage pipe at eastern corner of TP1
  - H2 Western tributary to Copperas Brook below TP1
  - H3 Between TP2 and TP3

  Sampling was done in March, April, and May of 1994 and again in June, July, and September of 1998.

- During April and August of 1998, approximately 35 locations were sampled by the U.S. Geological Survey (USGS) around the Elizabeth Mine Site as well as locations upstream and downstream on the Ompompanoosuc River (USGS, 1998). Most of these locations were in and around TP1. The metals analyzed for this study included an extensive list of metals (about 60) (see Appendix B for list), as well as water quality parameters.

  Sampling locations are named with identifiers such as LIZM-1 or OMPR-1. They also sampled the H3 reference location used by EMSG (1999). The report provides a map and a description of each sampling location, as well as the sampling results, however, no discussion of the results was provided.

- In August of 1990 the VTANR (1990) sampled surface water at three locations for a core group of metals plus pH (see Appendix B). The locations were:
  - SW-1 Between TP2 and TP3
  - SW-2 Background stream that flows in from east
  - SW-3 On Copperas Brook before confluence with the West Branch

  Additionally VTANR sampled ground water at several points; the following sample point is included in this summary:
  - GW-3 Air shaft to west, just south of Ompompanoosuc River

- During October and November of 1983 the Colorado School of Mines (COSOM, 1984) sampled 16 locations for a core group of metals plus pH. A conventional numbering system was used to name the points (1-16). Locations were around the

Site as well as down the Ompompanoosuc River at the site of the Union Village Dam.

- In the report entitled, "Union Village Dam Water Quality Evaluation Update," (USACE, 1984) the Army Corps of Engineers Hydraulics and Water Quality Section, Water Control Branch, Engineering Division provided surface water sample results from 1971 through 1983 for five stations on the Ompompanoosuc River. The primary metals of concern were copper, aluminum, iron, cadmium, mercury, and zinc; other parameters complied with state standards.
- In 1999, TetraTech NUS collected surface water samples from ten locations in the West Branch, Copperas Brook, and the Air Shaft. All samples were analyzed for metals only (TetraTech, 2000).

The data shown in Appendix C, and described below, are clustered according to physiographic characteristics of the mine area, including potential source areas, mixing zone areas within the Ompompanoosuc River, upstream areas, tributaries, and the East Branch of the Ompompanoosuc River. Data summaries include metals and other water quality parameters. Conventional pollutants, such as volatile organic compounds, semi-volatile organic compounds, and PCBs/pesticides were analyzed at a number of sample locations above, within, and below the mixing zone in the Ompompanoosuc River. No exceedances of applicable water quality criteria were found in these samples. Table 3 provides a summary of the EPA sample locations described below. The sample locations are also shown in Figures 1 and 2 in Appendix C.

Upstream of Mixing Zone: West Branch of the Ompompanoosuc River

Sampling locations upstream of the mixing zone along the West Branch of the Ompompanoosuc River include EPA Location 37 (horse farm upstream of South Strafford) and EPA Location 7 (bridge over West Branch at Tyson Road). In general, Vermont Class B water quality criteria are achieved at upstream locations with the exception of turbidity at the Tyson Road Bridge, which occasionally exceeds the 10 NTU standards. Aluminum concentrations are found above the ambient water quality criteria of 87 milligrams/liter (mg/L) in studies conducted by EPA and Army Corps of Engineers. Low level, exceedances of copper, iron, and zinc ambient water quality criteria have been observed at these locations, but in general, most metals are found below ambient water quality criteria. Values of pH in upstream locations range from 6.5 to 8.25.

Tributaries to the Ompompanoosuc River

Six sample locations have been included in the tributaries to the Ompompanoosuc River cluster of sample points. These include EPA Location 1 (Sargent Brook, upstream of mine road), EPA Location 18 (Abbott Brook), EPA Location 20 (Fullton Brook), EPA Location 22 (Lord Brook), EPA Location 24 (Jackson Brook), and EPA Location 39

(Lord Brook at New Boston Road). Locations 22 and 39 within Lord Brook may be considered to represent drainage from potential contaminant source areas. They are included here in the tributaries cluster, but treated separately.

Within Lord Brook (Locations 22 and 39), Vermont Class B water quality criteria are met for dissolved oxygen and turbidity. Exceedances of aluminum ambient water quality criteria were observed in Location 22, but not at Location 39 (which is located further upstream and closer to the potential source area). Sporadic exceedances of copper and lead were detected at these locations. In 1998, the USGS detected copper at a concentration of twice the ambient water quality criteria in Lord Brook at New Boston Road (EPA Location 39).

Vermont Class B criteria are met for most other tributary locations, with the exception of occasional turbidity exceedances. These were generally low-multipliers of the 10 NTU criteria. Aluminum concentrations routinely exceed criteria in 3 of the other tributaries sampled for this program (Locations 1, 18, and 24). Sporadic exceedances of ambient water quality criteria for copper were found at Location 24 in the EPA sampling events. Sporadic exceedances of lead and zinc ambient water quality criteria were noted in EPA Locations 18, 20. All exceedances are measured against hardness-adjusted ambient water quality criteria.

Samples were also collected by the EPA from three small tributaries to Copperas Brook and the Ompompanoosuc River, draining Copperas Hill (Locations 40 and 41) and Gove Hill (Location 36). In general, the results for Locations 40 and 41 indicate that there are no exceedances. Copper concentrations in Location 36 exceed criteria by a factor of six times from the July sampling event.

Mixing Zone in the West Branch

The mixing zone within the West Branch of the Ompompanoosuc River is defined by the discharge location of the Air Shaft at the upstream end and sample Location 42 at the downstream end. Sample Location 42 was defined as the fully-mixed zone on the basis of conductivity measurement transects at a number of locations downstream from the confluence of Copperas Brook and the Ompompanoosuc River. Seven sampling locations are included within the mixing zone cluster (EPA Locations 9, 10, 11, 12, 13, 14, and 15). Sample 42 is actually located within the cluster defined as “below mixing zone.” The mixing zone represents a stretch of the Ompompanoosuc River that receives unmixed or poorly-mixed waters from the Air Shaft and Copperas Brook source areas.

Sporadic exceedances of Vermont Class B water quality criteria are noted in most locations within this cluster for turbidity. However, dissolved oxygen criteria are met at all locations. EPA sampling within this zone detected exceedances of aluminum ambient water quality criteria at all sample stations, with exceedances ranging from 1 times criteria to as much as 200 times criteria (immediately downstream from the Air Shaft discharge). Copper concentrations in samples from this cluster exceed ambient water quality criteria on a regular basis at each sample location, with exceedance factors ranging from one times criteria to as much as 700 times criteria (TetraTech, 1999 directly below the confluence of Copperas Brook and the West Branch). Exceedances of ambient water quality criteria for iron and manganese are observed from all sampling locations within this cluster. Generally, sporadic low level exceedances of lead and zinc criteria are observed within the mixing zone as well; zinc concentrations at the confluence with Copperas Brook were found to be as high as 13 times criteria (TetraTech 1999).

Source Areas

Historically, the areas referred to here as potential source areas for contamination have been sampled by a number of researchers, beginning in 1983, up to the most recent sampling by the EPA over the past several months. Within this cluster, 10 EPA sampling stations have been defined as representing drainage from potential source areas, including the following:

- EPA Location 6 – confluence of Copperas Brook and the West Branch
- EPA Location 8 – Air Shaft discharge
- EPA Location 32 – addit located behind upper mine access road
- EPA Location 33 – drainage from open cuts
- EPA Location 2/3 – upper Copperas Brook above TP1 and TP2
- EPA Location 4 – Copperas Brook at culvert draining TP1
- EPA Location 5 – Confluence of seeps from TP1
- Seeps from TP1
- Seeps from TP2
- Seeps from TP3

These surface water samples represent a wide range of potential sources contributing to metals contamination of the Ompompanoosuc River and tributaries to the river.

For those locations where turbidity measurements were taken, Vermont Class B water quality criteria for turbidity is often exceeded. For those locations where dissolved oxygen measurements have been taken, Vermont water quality Class B standards are not met for the Air Shaft discharge. All other dissolved oxygen measurements at the EPA sample locations meet Class B standards.

Aluminum concentrations exceed ambient water quality criteria at all source area locations across nearly all studies. The highest concentrations of aluminum are found in seeps from the main tailings pile, in surface waters draining TP3, and in the culvert draining TP1, with exceedance factors as high as 2,000 times criteria. Cadmium ambient water quality criteria are exceeded at 8 out of the 10 source area locations, with the greatest exceedance factors located in seep samples and surface water samples draining the upper tailings (TP3). The USGS detected a concentration of 100 times criteria for cadmium in seeps from TP3 in 1998. Chromium concentrations were found to exceed criteria at seven out of the 10 source area sample locations, with exceedance factors as high as 25 times criteria (Vermont ANR, 1998-EPA Sample Location 5).

Copper concentrations were found to exceed ambient water quality criteria at all 10 source area sampling locations in nearly all sampling events. In general, the highest concentrations of copper were detected in waters draining from TP3. Iron and manganese concentrations exceed ambient water quality criteria at all 10 sampling locations for nearly all events. Zinc concentrations exceed ambient water quality criteria for all sample locations for nearly all events. Lead concentrations exceed ambient water quality criteria for 6 out of the 10 sampling locations on a sporadic basis. Where samples were collected for analysis of mercury, all concentrations fall below the ambient water quality criteria in the 10 source area sample locations. Sporadic exceedances of ambient water quality criteria are detected for nickel at most of the 10 sampling locations.

Below Mixing Zone Within West Branch of Ompompanoosuc River

Sample Location 42 within the West Branch is defined as the downstream extent of the mixing zone, below which surface water in the West Branch appears to be fully mixed. The cluster of sample locations defined as "below the mixing zone" begin with Sample Location 16 near Campbell Corner, and end with Sample Location 30, upstream of Union Village Dam. A number of historic studies have provided information from this stretch of the Ompompanoosuc River, including the 1998 USGS Report, 1999 Elizabeth Mine Study Group data, the USACE, and Dubois and King, 1983. In all, 12 sampling locations are represented by this cluster.

In general, Vermont Class B standards for dissolved oxygen are met at all locations. However, turbidity values exceed Class B criteria occasionally. Ambient water quality criteria for aluminum are exceeded at most sample locations within this cluster, from a combination of EPA sampling events (USGS 1998 and USACE 1984). Copper concentrations are found to exceed ambient water quality criteria (hardness-adjusted) at each sampling location. In most locations, the exceedances range from two times criteria to as much as seven times the ambient water quality criteria. The USACE detected copper at a concentration of 56 times criteria in 1984 at EPA Sample Location 25. Low level exceedances of lead ambient water quality criteria are observed in EPA data at several locations and USACE data from 1984. Manganese is found at concentrations exceeding ambient water quality criteria at EPA Locations 16 and 17, downstream of Abbott Brook. Sporadic exceedances of zinc ambient water quality criteria are found at Locations 16 and 25. Cadmium was detected by the USACE in 1984 at a concentration of 2 times criteria at EPA Location 25. Sporadic exceedances of iron criteria are observed throughout this zone, with generally low exceedance factors (1.5 times to 2 times criteria).

East Branch of the Ompompanoosuc River

Samples were collected by the EPA and the USACE within the East Branch of the Ompompanoosuc River on several occasions at two specific locations. Vermont Class B water quality standards are met for dissolved oxygen at EPA Location 35. However, occasional exceedances of turbidity are noted. Exceedances of ambient water quality criteria are observed from all sampling events for aluminum (up to 3 times criteria in the EPA studies and up to 40 times criteria in the USACE 1984 study). Low level exceedances for copper were detected in the EPA samples with higher-level exceedances detected by the USACE in 1984. EPA samples indicate that zinc concentrations exceeded criteria at EPA Location 35 by as much as 40 times. The USACE 1984 data indicate that exceedances for iron, lead, mercury, and zinc occurred at EPA Location 35 and exceedances for chromium and mercury were detected at Location UV-1A in West Fairlee, Vermont. The mercury exceedances range from one to five times criteria from this study.

Surface Water Quality Summary

While significant work must still be performed to fully define the constituents that represent a threat to public health or the environment, several general statements can be made based upon the data.

- The water quality of the West Branch and tributaries is of generally good quality. Some constituents were detected above state or federal criteria, but most were not significantly above the criteria or the exceedance was not consistent across sampling events. Aluminum appears to be most prevalent at levels above the federal reference criteria value of 87 micrograms/liter (ug/l). pH was also detected at levels above the VT Water Quality Standard range of 6.5-8.5.

- Copperas Brook and the Air Shaft discharge contain levels of several constituents many times greater than the upstream and background levels. Nine inorganic constituents: iron, manganese, aluminum, zinc, copper, cadmium, nickel, lead, and chromium were detected at levels above federal and state reference criteria.

- Six of the above constituents exceed federal or state reference criteria in the section of the West Branch just below the confluence prior to full mixing. Aluminum, copper, iron, lead, manganese, and zinc were all detected above reference criteria in this area. Cadmium, chromium, and nickel were not detected above criteria in this zone.

- Seven constituents (aluminum, copper, iron, lead, manganese, cadmium, and zinc) continue to exceed the reference criteria beyond the point where full mixing of Copperas Brook and the Ompompanoosuc River occurs. Below the mixing zone, a trend towards decreasing concentrations is apparent. The cadmium levels are quite low and sporadic in this area.

- The historical data for the East Branch show a wide range in concentrations for many constituents. Six constituents (aluminum, copper, iron, lead, manganese, and zinc) were detected above federal or state reference criteria.

In summary, the data from the West Branch of the Ompompanoosuc River below the Elizabeth Mine source areas (air shaft and tailings piles) strongly supports the presence of levels of aluminum, copper, iron, and manganese higher than applicable criteria and higher than in the West Branch above the Elizabeth Mine source areas. The levels of these constituents below the source areas clearly exceed those detected upstream or in the tributaries.

3.2 Sediment

River sediment samples were collected in 1989 by the USACE from three locations along the West Branch of the Ompompanoosuc River. Elevated levels of copper were noted downstream of the confluence with Copperas Brook as compared to upstream locations (at a maximum of 17.5 times higher). Other metals results were variable or not significantly different downstream versus upstream. In 1999, EPA Region I sampled the mouth of the Ompompanoosuc River in Norwich, Vermont. Sediments contained concentrations of copper, zinc, and total chromium that were described as “elevated” in the report. A sampling station approximately eight miles downstream of the confluence of the Ompompanoosuc and the Connecticut Rivers also had concentrations of copper and zinc described as “elevated” in sediments.

The COSOM (1984) sampled river sediments upstream and downstream of the confluence with Copperas Brook to evaluate the effect of modifying the Union Village flood control dam. The results showed that both total and available levels of copper, iron, and zinc increased with distance from Copperas Brook at sampling locations on the West Branch downstream of the Elizabeth Mine.

The USGS (1999) collected 22 co-located sediment and surface water samples near the mine, at the seeps, along Copperas Brook, at the air shaft, upstream and downstream from the air shaft, at Lord Brook and Blaisdell Brook (reference samples), and along the West Branch of the Ompompanoosuc River. Effects-range median (ERM) values for sediment toxicity are presented for comparison purposes in this report. All 22 samples were below ERM values for silver, arsenic, cadmium, chromium, mercury, nickel, and lead. All sediments from Copperas Brook exceeded ERM values for copper. Two sediment samples from the seeps exceed ERM values for zinc. None of the river sediment samples exceeded any of the ERM values.

The VTANR (1991) collected five sediment samples, three in conjunction with surface water samples and two in conjunction with ground water samples located at seeps at the base of TP1. The highest levels of arsenic, copper, lead, mercury, and selenium were found in Upper Copperas Brook, 250 feet above the point where the brook discharges onto the surface of TP2. The highest levels of zinc were found downstream of the base of TP1.

TetraTech NUS (2000) collected sediment samples in the West Branch of the Ompompanoosuc River above and below the Air Shaft, and above and below the confluence of Copperas Brook. Copper concentrations in sediment increased from above the Air Shaft (3.1 and 4.1 mg/kg), to below the Air Shaft (13.2 and 8.4 mg/kg) and below the confluence (292 to 2,310 mg/kg). Similarly, iron and zinc concentrations increased below the Air Shaft and below the confluence of Copperas Brook.

Similar to the past surface water investigations, the sediment data were collected at a variety of locations over an extended period of time and during several different seasons. The data may be used for comparison purposes. The USGS (1999) sediment data co-located with surface water data may be usable, however sampling methods and quality control results have not been provided. Significant data gaps remain relative to the nature and extent of metals contamination in sediment and the relative toxicity of these contaminated sediments to benthic organisms (see Section 3.5).

3.3 Tailings and Soil

In 1988, the USACE investigated the Elizabeth Mine to assess options for stabilizing and revegetating the tailings area. Surficial and subsurface tailings samples, taken 8 to 12 inches below the surface in TP1, revealed that the tailings are extremely acidic and contain relatively high concentrations of sulfate. Total zinc and copper levels were higher than typical for mineral soils, but relatively low in comparison to other mine wastes. Iron, zinc, manganese, copper, chromium, lead, and mercury were also found in the tailings (USACE, 1989). In 1991, the VTANR collected five samples from the tailings piles, some from the surface and some from the subsurface. One sample had a polychlorinated biphenyl (PCB) concentration of 0.22 milligrams/kilogram (mg/kg) in an area where transformers were illegally dumped on the tailings surface. Copper was found at concentrations ranging up to 765 mg/kg, lead up to 137 mg/kg, and zinc up to 376 mg/kg. Mercury was detected at a maximum of 0.325 mg/kg. Data gaps remain with respect to the nature and distribution of metals contamination in soils and tailings across the Site, and the mobility of those metals. Additional data were collected by the USGS (1999). pH measurements of soil from the upper waste pile ranged from 2.1 to 3.2, the middle tailings pile had pH measurements greater than 5 and the lower tailings pile had pH values around 3. Other metals were also measured, including copper, cadmium, iron zinc, and lead.

3.4 Ground Water

VTANR (1991) collected ground water at three locations, including two seeps and the flooded air shaft. The results indicate that detectable levels of copper, nickel, and zinc were found at the air shaft, and the seep samples had detectable chromium levels. None of the levels exceeded human health drinking water standards. Several piezometers are situated around the Site, but there are no permanent monitoring wells for groundwater collection. Arthur D. Little, Inc., has installed ten piezometer clusters in the tailings for geotechnical purposes.

Residential well samples were collected by the VTDEC and USGS prior to 2000. These samples did not reveal any constituents above EPA's drinking water quality criteria, Maximum Contaminant Levels (MCLs) or state standards. EPA has began sampling residential wells in 2000. Two wells, located on a single property, were found to be of poor quality with elevated concentrations of aluminum, cadmium, copper, iron, and manganese. The other wells have met federal and state primary drinking water standards. The past ground water data do not provide adequate characterization (chemical or physical) of the ground water in the mine area.

3.5 Biota

Both benthic invertebrates and fish species were studied in the past in the West Branch of the Ompompanoosuc, above and below the confluence with Copperas Brook. The location of testing above the confluence (considered a reference location, a location unaffected by mine drainage) for all studies was in the area of Tyson Road downstream of South Strafford, a similar habitat to the West Branch below the confluence. The West Branch above South Strafford, which consists of different habitat types (pastureland, mud bottom, no riffles, runs, and pools) than those further downstream, was not sampled or used as a comparison or reference area for biota studies.

Benthic Invertebrates

The EMSG trained local volunteers to monitor for benthic macroinvertebrates in 1998 (EMSG, 1999). This group found a marked decrease in abundance and biodiversity in the West Branch of the Ompompanoosuc below its confluence with Copperas Brook as compared to upstream (reference) locations (just upstream of Tyson Road crossing). The downstream macroinvertebrate community of the West Branch is low in density, poor in species richness, poor in EPT richness, and is dominated by one species. This monitoring program was continued at seven stations, sampled three times from 1998 to 1999 (EMSG, 2000). The results show similar patterns of adverse downstream biological impact for the West Branch from all three sampling dates. Total densities and EPT richness were highest at the reference site and generally declined moving downstream of the confluence. Community composition changed dramatically at a sampling station immediately downstream of the confluence, with the community becoming dominated by true flies, especially midges. Mayflies almost disappear, then reappear at a site further down the river.

The report concludes that the effects of the acidic and metal-laden leachate are reflected in the reduction of abundance and diversity and a change in community composition of benthic macroinvertebrates. EMSG data (five sites collected on four dates) were evaluated in greater detail in a Master's Thesis (Burke, 1999). The evaluation used EPT richness, total taxa richness, relative abundance, percent of the most dominant taxa, and percent model affinity. The results indicated, again, that the portion of the river below the mine is degraded, and that the recovery of normal benthic communities does not begin to occur until the main branch of the Ompompanoosuc River. The control site, above the confluence with Copperas Brook at Tyson Road, reflected the highest degree of ecological health based on the metrics used for data analysis. The next healthiest site was the recovery site on the main branch of the Ompompanoosuc. The three sites in the West Branch of the Ompompanoosuc below the confluence with Copperas Brook were all similar in their levels of impairment. The site 3.5 miles downstream from Copperas Brook consistently appeared to be the most impaired portion of the river.

Finally, benthic community data received from Doug Burnham of the VTANR, for the years 1986, 1987, and 1998, compare macroinvertebrate biometrics from above (Location 7, above Tyson Road) and below the confluence of Copperas Brook with the West Branch (Table 4) (Burnham, 2000). The data clearly show a biological impairment downstream, based on a decrease in biometrics from above to below the confluence. The results are compared to both reference median values for the State of Vermont and VTDEC proposed biocriteria for Class B streams based on state-wide results. The relatively good ecological health of the upstream waters and the benthic reference habitats contrast sharply against the degraded conditions of the downstream waters.

Older data from the State of Vermont (Fiske, 1987) also found decreases in density, richness, EPT richness, and overall community similarity. The data from three years of sampling (1983, 1986, and 1987) were consistent in locations downstream of the mine as compared to upstream and other reference locations. The community density below Copperas Brook (the influx of the mine leachate) decreased by over 95 percent all three years. The richness (total number of species) also decreased at downstream locations by 56 percent, 67 percent and 89 percent, respectively, all three years. The EPT index similarly decreased at downstream locations all three years by 93 percent, 69 percent, and 92 percent, respectively. There was a poor similarity between the upstream and downstream sites of less than 15 percent. A similarity of below 0.25 (comparing unaffected versus affected locations) is found when major alterations to the community have occurred.

Fish

The USACE (1990) collected twenty black nose dace from each of four collection areas of the West Branch. One collection area was upstream of the Copperas Brook junction, while the remaining three collection areas were below the junction. Fish samples were analyzed for metals, including: barium, cadmium, chromium, copper, iron, lead, manganese, and zinc. Levels of copper, chromium, zinc, barium, and iron were significantly higher in fish downstream than in those from upstream of the mine, while elevated levels of manganese and iron were noted in only one sampling area, the area closest to the confluence with the East Branch. The USACE concluded that the results may indicate that the samples were contaminated by fine sediments adhering to gills or other external surfaces, rather than from bioaccumulation in tissues.

The USACE (1990) also conducted biomass studies of forage species fish (dace, sculpin, sucker). Two upstream and two downstream locations were sampled; the authors state that the areas were "typical of upper reaches of the West Branch of the Ompompanoosuc in terms of percent instream and bank cover, percent riffle and pool, and substrate type." Results showed that the biomass of the forage species upstream of the mine was 4.5 kg/ha, while downstream it was 1.3 kg/ha (a reduction of 71 percent) indicating that the mine effluent has adversely impacted populations of forage species downstream of Copperas Brook. Total fish biomass was 4.7 kg/ha upstream and 3.7 kg/ha downstream. However, the authors state "Forage species biomass is probably a better index of mine impacts on stream productivity than total fish biomass, because many of the trout occurring downstream of the mine are likely to be migrants from stocked tributary streams." A similar study conducted by the VTDEC noted a reduction of 86 percent between upstream (1,858 kg/ha) and downstream (253 kg/ha) fish communities (Langdon, 1987). Other parameters (IBI, species diversity, and trophic composition) were little or no different between sites, however, the author notes that these parameters do not generally reflect impact in toxic situations. Although the author notes that the physical habitat of sampled sites differed somewhat, possibly accounting for some differences in abundance, this factor alone would not explain the downstream decline in abundance.

The State of Vermont (Fiske, 1987) concluded in their preliminary evaluation of biological impairment to the Ompompanoosuc River (a macroinvertebrate survey in conjunction with the VTDEC fish study conducted by Langdon, 1987) that there was an impact on the fish population below the mine influence that indicated a toxic effect and that the overall integrity of the aquatic biota below the mine discharge points "remains extremely poor."

Fish were collected in the West Branch above (just upstream of Tyson Road crossing) and below the Copperas Brook confluence by trained volunteers in 1998 (EMSG, 1999). The downstream fish community was found to be low in density, having fewer than the expected number of species and a greatly reduced density, relative to upstream conditions.

The biota data collected in the past (as outlined above, e.g., EMSG, 1999, EMSG, 2000, Langdon, 1987, Burnham, 2000, Fiske, 1987) clearly show an adverse effect of the Elizabeth Mine drainage on biota in Copperas Brook and the West Branch of the Ompompanoosuc River. These data may be used in the future as the basis for designing further studies to more clearly delineate the extent of affected aquatic habitats and the degree of impairment.

4.0 Current Site Conditions

This section briefly describes the current Site conditions, including existing building structures, tailings piles, environmental setting, hydrology, and a summary of local residential water supplies. The property and surrounding areas are shown on Figure 2, the current USGS topographic map.

4.1 Existing Buildings

Mining and ore processing operations ceased in the 1950s. Many of the buildings used during this period remain, however, their structural condition is generally poor (see Figure 12). The processing equipment was removed, likely by salvage operations, and portions of the main processing buildings (crushing plant, flotation plant) have collapsed. Two buildings on the property are rented for residential purposes, along with a garage to store equipment. The Site also contains numerous old abandoned cars and trucks. There are no remaining structures from earlier operations, however, remnants of former buildings (stone foundations) can be found in several areas around the Site. Foundations and remnants of processing equipment from early copperas "factories," located below TP3, can be observed today.

4.2 Tailings

Mill tailings are located in three general areas around the Site, designated TP1, TP2, and TP3. TP1 and TP2 are finely ground materials of sand and silt consistency, covering approximately 32 acres and 5 acres, respectively. These tailings piles result from the most recent copper mining and milling operations of the 1940s and 1950s. An aerial photo from 1939 shows a small tailings pile situated in the floor of Copperas Creek valley, in an area now covered by later tailings (TP1). TP1 forms a broad flat plateau, with a maximum depth thickness of approximately 110 feet. The north and west faces of TP1 are steeply sloped (ranging from 1.3:1 to 17:1) and subject to wind and water erosion (USACE, 1989). The downhill face of the tailings has formed a fan-shaped delta at the base of the tailings piles (COSOM, 1984).

TP2 is located to the southwest of TP1. This area is a smaller plateau that rises about 30 feet above TP1. There is a steep slope on the northern end of TP2 that slopes down to TP1. The tailings in TP1 are similar to those found in TP2 (USACE, 1989). Copperas Brook flows freely through an erosional cut in TP2.

TP3 is located to the southwest of the other two tailings piles, in the headwaters of Copperas Brook, just east of the North Cut (open-pit). This tailings pile, resulting from the earlier copperas-producing operations, is approximately six acres, with many small mounds of red to yellow course-textured materials. The material in TP3 is the remaining roasted and leached pyrrhotite ore from early copperas extraction processes. There are other smaller tailings piles throughout the Site (EMSG, 1999).

Smelter slags can be found at several areas around the Site as a result of early copper smelting operations. Furnace Flats, located along the banks of the Ompompanoosuc River is built, in part, on slag material from Isaac Tyson's original smelting operation. Slag piles can be found on the opposite side of the river and in the Seargent Brook drainage basin, adjacent to later Tyson smelting operations.

4.3 Environmental Setting

The historic mining activities occurred along an elongate (north-south) ridge, cresting on Copperas Hill. Most mining production was from underground workings, but two significant open pits remain from early mining (North Cut) and later (1940s and 1950s) mining (South Cut). Most historic ore processing occurred in the Copperas Brook valley in an area currently covered by tailings.

Portions of TP1 have been covered with approximately 6 inches of topsoil by a local land-owner as part of a previous effort to revegetate the tailings and reduce wind-blown dust. Sparse vegetation and immature trees can be found over these portions of the pile. Surface water runoff at the foot of TP1 has impacted an area measuring several acres; remnants of the former trees can be seen in this area. The deforestation is attributed to sedimentation and acid mine drainage from the tailings. TP2 supports a small stand of birch and small hemlock trees. TP3 is generally devoid of significant vegetation, except for a few small birch and white pine trees growing between the tailings mounds (USACE, 1989). Low pH and poor soil conditions is the likely reason for little to no vegetation in this area.

The West Branch, Ompompanoosuc, and Connecticut Rivers are all considered potential fisheries. Species indigenous to the West Branch and Ompompanoosuc Rivers include brown, brook, and rainbow trout. The Connecticut River also supports largemouth bass, smallmouth bass, pike, pickerel, perch, walleye, bullhead, and pan fish (EPA, 1999).

4.4 Hydrology

Copperas Brook and several small seasonal tributaries form the principal surface water drainage in the mine area. Copperas Brook has reportedly run dry during particularly dry summer months. Copperas Brook originates in the southwest portion of the Site at the base of TP3, and drains the area from Copperas Hill to Gove Hill. Since the mine has been closed, the drain pipes installed during the 1943 to 1958 period have been destroyed and Copperas Brook now flows onto TP1, forming a small pond. Most of the pond water flows out through an existing decant tower, however, vertical percolating through the tailings occurs at an unknown rate. Copperas Brook discharges to the West Branch of the Ompompanoosuc River, approximately 2,000 feet north of TP1.

On the basis of sampling conducted in the spring and summer of 2000, Arthur D. Little Inc. has estimated that at the confluence of Copperas Brook with the West Branch of the

Ompompanoosuc, an average of 151 pounds/day of copper, iron, aluminum, and zinc are discharged, with the majority (78%) being iron. The average flow of Copperas Brook at its confluence with the West Branch was measured as 260 gallons/minute. A flooded air shaft drains the lower portion of the mine complex and discharges directly to the Ompompanoosuc River, to the northwest of the Site. An average of 17 pounds/day (lb/day) are discharged from the Air Shaft, based on the most recent data described above. Water flows from this 1-foot diameter air shaft, and a mound of precipitated iron oxide has formed, which is approximately 2 feet high and 40 feet in diameter (COSOM, 1984).

The West Branch of the Ompompanoosuc River originates approximately 10 miles northwest of the Copperas Brook confluence and ends approximately 4.5 miles downstream of the juncture where it joins the East Branch of the Ompompanoosuc and is known, thereafter, as the Ompompanoosuc River. The river flows approximately ¾ mile further to the Union Village Flood Control Dam. The Ompompanoosuc joins the Connecticut River approximately 5 miles downstream of the dam (VTANR, 1991).

Wetlands mapped in the vicinity of the mine include riverine, palustrine, and lacustrine systems. The riverine systems are found along the West Branch, and the lacustrine wetlands are located in the two open mine pits. The pond on TP1 is a flooded/temporary wetland (VTANR, 1991).

4.5 Residential Water Supplies

Residents of the town rely on individual water supplies such as springs, dug wells, or drilled wells. The nearest wells are located on the mine property itself and serve a number of local residents along Mine Road. Total population served by ground water sources within a four mile radius of the Site is approximately 1,388 (VTANR, 1991).

5.0 Data Gaps

This section describes general data gaps, followed by data gaps related to potential source areas. This is a preliminary identification of data gaps. The RI/FS Work Plan will present a thorough evaluation of the data gaps and present the investigations that will be implemented to address the data gaps.

5.1 General Data Gaps

In general, the past data for surface water, sediment, and biota have been gathered sporadically, often using different methods, and were collected over different time periods in different locations, so that data cannot be compared. Using the past data alone, we are not able to fully understand the influence of the Elizabeth Mine on the ecology and habitat of the area's streams and rivers.

The historic surface water sampling described in this report indicates a high degree of inconsistency between unrelated sampling events. These sampling events occurred over a time period of interest to future studies and can, therefore, help by providing historic context and insights into the full nature, extent, and seasonality of surface water contamination. We conclude, however, that the past surface water data contain gaps and although these data may be used for comparison purposes, they cannot provide a full understanding of the Site's surface water quality. The historical environmental data can be used to support the more general statements regarding the impact of the mine on the surface water, however, the historical data may not be able to provide a baseline to evaluate future actions and to establish trends in concentrations.

Similar to the past surface water investigations, the sediment data were collected at a variety of locations over an extended period of time and during several different seasons. Significant data gaps remain relative to the nature and extent of metals contamination in sediment and the relative toxicity of these contaminated sediments to benthic organisms.

The biota data collected in the past clearly show an adverse effect of the Elizabeth Mine drainage on biota in Copperas Brook and the West Branch of the Ompompanoosuc River. Future studies must more clearly delineate the extent of affected aquatic habitats and the degree of impairment.

For surface water and sediment, the EPA has designed and is currently conducting an on-going surface water and sediment monitoring program to begin the process of filling these data and knowledge gaps. The RI/FS will complete the process of identifying and collecting the data to address all Site data gaps. In addition, the initial biota study will substantially improve the knowledge regarding these Site impacts and further address questions associated with biota abundance and survivability in the West Branch below the confluence with Copperas Brook.

As discussed further below in Section 5.2, data gaps remain with respect to the nature and distribution of metals contamination in soils and tailings across the Site, and the mobility of those metals. In addition, the past ground water data do not provide adequate characterization (chemical or physical) of the ground water in the mine area. As stated above, the RI/FS Work Plan will address the data gaps.

5.2 Data Gaps Related to Potential Source Areas

There are four principal potential sources of environmental contamination at the Elizabeth Mine Site:

- TP1 and TP2
- TP3 (Former heap-leach piles)
- Open mine cuts (North Cut and South Cut)
- Air shaft (vent)

Other potential sources include waste rock from historic mining that can be observed in a number of locations around the Site, but are generally found in small, relatively insignificant quantities. One large pile is present east of the South Cut, adjacent to the unpaved access road. Smelter slag is observed in several areas around the Site, but is not considered leachable, and hence, not a likely source of contamination. Acid mine drainage from the main adit contributes a small amount of metals and acidity to the overall drainage system.

Potential Source No. 1: Tailings Pile 1 and Tailings Pile 2: Surface water sampling to date has confirmed the presence of elevated metals concentrations and low pH in water seeping from and running off these main tailings piles. In their current condition, these piles also act as a source of significant sediment loading to the Ompompanoosuc River. They are grouped here as a single contaminant source because they are similar in composition, they were deposited within roughly the same time frame (1940s-1950s), and any remedy designed to address these deposits would likely deal with them in a similar manner. The main contaminants of concern include the metals copper, aluminum, zinc, and, to a lesser extent, cadmium. Other metals occur in surface water runoff and seeps from these piles, but do not appear to be as significant.

Data Gaps: There are currently a number of important data gaps regarding the subsurface hydrology and surface water infiltration related to these piles. Any future cleanup action must address the interaction of ground water with the piles and the rate and nature of surface water infiltration from storm events and from Copperas Brook. This data will allow for a determination of the relative contributions of ground water and surface water to the seeps breaking out at the toe of the north slope of the tailings must be understood and addressed. Further, structural stability and geotechnical characteristics of the tailings pile margins (north and west slopes) is not currently understood. The area immediately north of TP1 requires complete characterization from a structural stability perspective. These issues are likely to be part of pre-design and design studies for a NTCRA or will be part of the data collected during the RI/FS.

Ground water quality impacts around the tailings are not understood at present. This issue will be addressed as part of the RI/FS.

Potential Source No. 2: Tailings Pile 3: This tailings pile is referred to in this report as the former copperas heap leach area. This area is similar to the heap leach gold extraction processes found in many western states. Crushed pyrrhotite ore (iron sulfide) was roasted along the steeply sloping east side of the north mine cut from 1810 to about 1880. The "roasting" was done in large piles on the slope to oxidize the sulfide complex, rendering the material highly leachable with water. Water from spray hoses or rain events percolated through the ore pile to the underlying bedrock and trickled downslope to a collection pond and series of troughs, where it was gravity-drained to two evaporator/crystallizing plants. The remnants of the leach piles are observed today as bright red and yellow colors. The red piles appear to be completely roasted sulfide ore, largely hematitic iron oxide today with little remaining sulfide. The yellow piles are partially roasted sulfide ores that contain high concentrations of unroasted pyrrhotite.

Today, rain events perform the same function that they did during the 1800s by leaching iron sulfate from the partially roasted sulfide ore. In addition to iron sulfate, this leach pile continues to contribute other toxic metals to the surface water environment and results in low pH through acid generation. The lowest surface water pH conditions on-site and the highest metals concentrations are consistently found in the upper reaches of Copperas Brook at the bottom of this leach area.

Data Gaps: There are a number of data gaps related to this area. The depth to bedrock and thickness of roasted ore in this area is not completely understood. The structural stability of these materials must be understood before any potential remedy can be considered. The lateral extent of the material needs to be confirmed to support volume calculations. The chemistry of these materials has been well documented by the USGS (e.g., USGS, 1989) and does not require further evaluation for engineering purposes. The ground water conditions are not known in this general area. These issues are likely to be part of pre-design and design studies for a NTCRA or will be part of the data collected during the RI/FS.

Potential Source No 3: Open Mine Cuts (North and South): The two open mine cuts will act as an ongoing source of contamination to ground water. Low pH conditions from oxidation of sulfide minerals results in leaching of metals from the rock.

Data Gaps: The open mine cuts provide oxygenated water to the remaining sulfide minerals in the wall rock and function as a potential source of metals contamination in ground water downgradient of the cuts. Very little is currently understood regarding ground water hydrology in the mine area. Data gaps remain regarding both the physical and chemical aspects of ground water in this area.

Potential Source No. 4: Air Shaft (Vent): Underground mining operations extended north from the open cuts beyond the Ompompanoosuc River. An air vent was constructed on the south side of the river. The surface expression of this vent is an iron pipe, nearly flush with the ground surface, measuring approximately one foot in diameter. Water flows from the underground workings to the surface through this pipe on a continuous basis. Surface buildup of iron oxides are evident from the Furnace Flat area on the north side of the river. Discharges from this vent pipe to the Ompompanoosuc River result in continuous metals loading.

Data Gaps: Any effort to eliminate this constant-flow decant point from the mine workings must address a number of data gaps to be successful. The relationship of ground water flow within the mine workings from this point to other possible breakout points must be understood. These issues are likely to be part of pre-design and design studies for a NTCRA or will be part of the data collected during the RI/FS.

Many other data gaps are likely to be identified as part of the development of the RI/FS Work Plan. Examples of other data gaps include: wind blown dust; off-tailings soil quality; and drinking water supplies.

6.0 Site Summary Report Conclusions

The SSR was developed to act as an interim report that would provide individuals working on the Elizabeth Mine Site a summary of the Site history, environmental data, and existing conditions to better prepare these individuals to participate in Site discussions. The report is not intended to be a comprehensive and precise evaluation of the environmental risks posed by the Site or the complicating factors in assessing these risks (such as background conditions). The SSR is not intended to be a basis for EPA action, but rather is a tool that assists the Site team.

The final SSR represents a revision to the initial SSR based on comments from the CAG and other reviewers.

7.0 References

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Table 1. Periods of Operations Described in Site Summary Report

Date	Operations	List of Major Owners
1793 – 1810	Early Exploration	Asahel Chamberlain
Period I 1810 – 1870	Large-Scale Copperas Production	Vermont Mineral Factory Company Boston Copper Mining Company Vermont Copper Mining Company Copperas Hill Mining Company Vermont Copperas Works New England Chemical Company
Period II 1830 – 1930	Early Copper Production	Elizabeth Copper Company Strafford Mining Company Vermont Copperas Company Sharon Power Company Vermont Copper Company American Metal Company National Copper Corporation
Period III 1942 – 1958	World War II Era Copper Production	Vermont Copper Company Appalachian Sulfides, Inc.

Table 2. Summary of Environmental Investigations (two pages)

Table 3. Elizabeth Mine Surface Water and/or Sediment Sampling Locations (1 page)

Table 4. Macroinvertebrate Metrics from the West Branch of the Ompompanoosuc River

							Reference Median	Class B Biocriteria
Date	Sept 86	Sept 86	July 87	July 87	Sept 98	Sept 98	Sept-Oct	Sept-Oct
Density	534	25	286	7	1492	109	1919	>300
Richness	40.5	13	43	5	49	21	48	>30
EPT	30.5	9.5	22	2	26	15	27	>18
PMA-O	72	73	74	46	93	69	83	>45.0
BI	2.99	4.55	4.20	2.57	3.19	3.89	3.1	<5.00
%Oligocheata	0	0	0	0	0	0	<1	<13.0
EPT/EPTc	0.99	0.90	0.66	0.50	0.89	0.99	0.86	>0.45
PPCS-F	.53	0.56	0.38	0.43	0.74	0.39	0.64	>0.40
Assessment	Good	Poor	Good	Poor	Exc	Fair		

Provided by Burnham, 2000.

Data from above and below (shaded) the Elizabeth Mine site for three years, and two seasons. The reference median values from VTDEC medium mountain streams, and the associated proposed biocriteria for Class B.

Insert here:

Figure 1. Digital Orthophoto with Property Boundaries from Current (1990s) State of Vermont

Figure 2. U.S.G.S. South Strafford Quadrangle Topographic Map

Figure 3. 1890 Topographic Contours Superimposed on Current (1990s) State of Vermont Orthophoto

Appendix A: Outline History of Elizabeth Mine, Strafford, Vermont

Appendix A: Outline History of Elizabeth Mine, Strafford, Vermont

Date	Event
1793	Traditional date of discovery of outcropping of iron oxide
1798	First recorded reference to minerals when Asahel Chamberlin reserves to himself "the privilege of digging iron ore" on land he is selling to Jacob Stevens.
1809	The Vermont Mineral Factory Company chartered in Boston to produce iron sulfate or copperas from the pyrrhotite in the ore. Deed of 30 September 1809 refers to digging ore and making copperas as now being in progress. Deed of 29 August 1811 specifically refers to its having erected "works for the purpose of manufacturing copperas." Subsequent deeds show company extending its property and mineral rights (all on upper reaches of Copperas Hill). By 1827 or earlier the company owns a boarding house and farm which it leases to a contractor to provide lodging and basic services of washing and mending for its workmen et cetera.
1830	The Vermont Mineral Factory Company acquires land, mill privilege and other amenities near the Ompompanoosuc river, where it builds a dam to harness water power in the first efforts to develop the copper in the ore; major investment; Isaac Tyson Jr. of Baltimore brought here from Baltimore, Maryland, to superintend both copperas and copper works. Expansion of mineral rights into other areas of town. By 1834 there were up to eight furnaces "at the river," with a dam, a water wheel to drive the blast machinery; experiments with heating the air for the blast with anthracite or the more readily available charcoal; elsewhere on the property were roast beds (which prepared the ore for smelting by driving out the sulfur), calcining ovens, and kilns for manufacturing the paint pigment Venetian red. A new road connected the hill and river areas. The works at the river appear to have been owned or at any rate controlled by a new entity, the Boston Copper Mining Co., a Massachusetts corporation that may or may not have received a Vermont charter later. This company's name appears in our Grand List or property assessment records but not in the land records where conveyances are recorded.
1837 or 1839	Earliest copper furnaces closed down
1839, February	Merger of the Vermont Mineral Factory Company with a smaller, related copperas producer in Shrewsbury, Vermont, to form the Vermont Copperas Company, a corporation duly established by the laws of the State of Vermont. Conveyances include listings of copperas inventory on hand but no reference to copper.
1850	Trying to tap the vein that continued underground from the open cut, the Vermont Copperas Company drove an adit horizontally into the hill from the southeast. This missed the vein by passing under it, but enough ore was found to produce copper throughout the Civil War. The location of the company's small smelting furnace from this period is not known. Teamsters carried copperas and copper ore to Pompa Depot in Norwich on the Connecticut River, the railroad having reached the area in the 1840s.

Appendix A: Outline History of Elizabeth Mine, Strafford, Vermont (continued)

Date	Event
1853, November	A note on the adjoining town of Vershire, where Isaac Tyson, Jr., and his associate Amos Binney had tried to find a copper vein in the 1830s, incorporation of the Vermont Copper Mining Company. Its mine, later known as the Ely Mine, completely overshadowed any copper production in Strafford through the rest of the 19th century and beyond. Its story is very different from that of Strafford. There were no corporate links between the Strafford and Vershire mines, but engineers and managers had some contact, and miners worked at whichever mine offered employment at any particular time.)
1864, April	Vermont Copperas Company conveyed the mineral rights in the old, so-called South Mine property (on the Strafford / Sharon town line) to the Copperas Hill Mining Company. a corporation duly organized within and under the laws of the Commonwealth of Massachusetts. Deeded back to Vermont Copperas Works October 1865.
1861-1865	A Vermont State Board of Agriculture, Manufactures and Mining for the year 1872 states that a new smelting furnace was erected at Strafford during the early part of the Civil War, that "the business was pushed with a good deal of energy and was found profitable," and that the mine then employed about one hundred men. With the end of the war, government demand for copper ceased and accumulated stocks were thrown on the market.
1866, March	Vermont Copperas Company mortgages to Colonel James M. Thompson of Springfield, Mass., "all the mines, factories, furnaces, mills, millsites, dams, water-power, and lands belonging to said Company mainly in towns of Strafford and Norwich estimated 300 acres together with all the buildings of whatever descriptions thereon, consisting in part of two copperas factories, with boilers, crystalizers, and other fixtures thereof, one paint factory, one barrel factory, one saw mill, four smelting furnaces, agent's house and office, boarding house, tenements for workmen, barns, sheds, shops, &c. &c. at Copperas Hill [and at the river] in Strafford and the Depot building and land appurtenant thereto at Pompanoosuc Station.
1866, October	Vermont Copperas Company buys additional land in area of Furnace Flat.
1867, June	Col. Thompson petitions Court of Chancery, Chelsea, Vermont, for foreclosure; trustees appointed.
1868, January	Col. Thompson and trustees convey all the same "mines, factories, furnaces, mills, millsites, dams, water-power, and lands" as above to the New England Chemical Company, a corporation duly established by the laws of Vermont. Some subsequent references to this company call it the New England Chemical Manufacturing Company. The company reportedly planned to work the mine not only for copper and copperas but also to produce drugs, paints, chemicals, acids, oils and fertilizers.
1869, April	Stockholders of New England Chemical Company, Inc. voted to borrow $50,000 on mortgage; its property includes some real estate in Malden, Massachusetts, used in the manufacture of sulfuric acid from ore shipped from Strafford.
1874, May	The year of the Plan of the Property. All the property of the New England Chemical Company, together with its "good will" including use of company's brands, marks and names, sold at auction to William H. Foster of Brookline, Mass., who appears to have been treasurer of the company.

Date	Event
1877, November	William H. Foster leases to Joseph W. Cleaveland "the copperas works and copper mines belonging to him, in the towns of Strafford, Sharon, Thetford and Norwich ... Vt, with land appurtenant thereto, being upwards of three hundred acres of land ... including mills, water power, factories, cooperage and the like, but excepting all wood land and standing wood on said premises. Also the depot building and land appurtenant thereto, at Pompanoosuc Station ...Norwich ... also the tools, teams, and other personal property except wood hay and grain belonging to said Foster and used in connection with said works, which are to be inventoried and valued ..." various further conditions spelled out.
1881, September	William H. Foster and his associate John D. Bryant convey about 35 acres of their premises to James W. Tyson and his brother Jesse in exchange for another similar parcel.
1882, October	William H. Foster, conveys the "mines, factories, furnaces, mill, mill sites, dams" to the Strafford Mining Company, a corporation duly established and organized under the laws of the State of Maine and of which he is the president; lease to Cleaveland to run to 1 December 1882. On the same day, the Strafford Mining Company having authorized William H. Foster to borrow $50,000, the property is conveyed in trust to the company treasurer and another.
1872, April	James W. Tyson, son of Isaac Tyson, Jr., begins to acquire mining rights that had formerly belonged to his father's partner, Col. Amos Binney, later acquiring new properties including the farm where we now have the remaining WW2 buildings and probably the tailings piles also.
1882, February	James W. Tyson conveys various properties and rights to the Elizabeth Mining Company incorporated and named in honor of his wife. Company will own rights on area running north of the [dry] open cut. Refused entrance to his mine through the Foster-Cleaveland land, he sinks vertical shafts near the southern edge of his property at the top of the ridge. Ore reportedly shipped south (Connecticut?) for smelting.
1882, 22 July	Tyson equipment expansion, with three stationary engines, large boiler and a mammoth crusher installed.
1882, November	Town of Strafford lays out for the Elizabeth Mining Company a public highway running in a southerly direction from today's Mine Road (near Woody Tyson's house?), evidently up the west side of Copperas Hill roughly along the path of a small brook (Sargent Brook); this is to be a pent road, with gates allowed, and is to be maintained by the company and to be in force only so long as it or its assigns use it "for mining and smelting purpose chiefly." This road would be useful when, under the direction of James W. Tyson Junior, ore was taken down from the ridge over the west side of Copperas Hill to roast beds and furnace(s) near the old turnpike.. Roast heaps burned "roasted" for about twelve weeks. Produced copper matte refined to "black copper" of 96 to 98 percent purity. Tyson also gets an existing road (Mine Road or Tyson Road probably) altered to give a gentler grade up from present Route 132 to the mine.

Appendix A: Outline History of Elizabeth Mine, Strafford, Vermont (continued)

Date	Event
1884, March	James W. Tyson purchases a farm that becomes the family home in Strafford.
1886	Tysons reported to have sunk a vertical shaft 160 feet deep.
1888	Child's Gazetteer of Orange County states that as of that date, nothing was being done by Tyson or by Foster's Strafford Mining Company.
1890, April	Elizabeth Mining Company borrows $50,000 and mortgages its property. Loan is repaid and mortgage discharged in January 1899. For several years, the mine opens and closes according to rise and fall of price of copper, with short-lived periods of work in full force interrupted by abrupt shutdowns.
1896	Elizabeth Mining Co. drives a new 1400-foot adit from the east side of Copperas Hill, located near the buildings remaining from the WW2 operations. Company ran a concentration mill, roast beds and furnaces in that general area for a few years.
1899, January	As noted, $50,000 mortgage of 1890 discharged; company votes to increase its capital stock to One Million Dollars and to divide the same into shares of five dollars each.
1904, May	Failure of Elizabeth Mining Company; Court of Chancery, Orange County appoints James W. Tyson Jr. as Receiver.
1904, May	John N. Judson and Lewis G. Rowand lease from James W. Tyson, Jr., Receiver, a portion of the Elizabeth Mining Company's land and buildings including openings, smelters, adits, railways, roast yards, engines, engine & boiler houses, boarding houses, etc., plus water rights, for two years ... plus right to mine 10,000 tons of the run of the mine and roast, separate concentrate and carry away, and also use 10,000 tons from the unroasted ore now mined and on the dumps or waste heap without paying therefor ... pay a royalty for ore over above amounts at a rate related to current price of electrolytic copper cathodes; to pay at least $2,500; option to purchase property for $250,000; lease may be terminated by J&R on 60 days' notice; various other terms and conditions.
1905, February	Judson and Rowand being unable to carry out their original intentions because of the failure of their magnetic separation plant, Court allows Receiver to grant a one-year extension of their lease; lessees are to erect, construct and put into practical operation before 1 November 1905 a plant capable of handling at least 100 tons per 24-hour day, the plant to cost not less that $25,000. Additional security required, provided by August Heckscher.
1907, March and April	August Heckscher buys various parcels of land in Strafford, Furnace Flat area.
1907, September	Heckscher conveys these parcels to the Vermont Copper Company, a corporation of the State of Delaware.

Appendix A: Outline History of Elizabeth Mine, Strafford, Vermont (continued)

Date	Event
1907, 9 November	Heckscher purchases the mortgaged property of the Strafford Mining Company, which appears much diminished from its earlier appearances in the records: the depot and land at Pompanoosuc had been conveyed to the Boston & Maine RR; the Strafford buildings, dams and other structures had been "largely removed and carried away," and the ores mined and removed. The property consisted of two parcels of land, respectively, 328 acres and 28 acres (at the river). Date when the company's active operations ended not clearly established (but see 1888 above) This property conveyed by Heckscher to the Vermont Copper Company of that era, in February 1908.
1907, 19 November	Heckscher purchases 597 acres more or less, together with various mineral rights, the property of the Elizabeth Mining Company. In addition to purchasing all the land previously developed for copperas and copper mining and production as well as some new lands, Heckscher organized a power company to build a dam on the White River below Sharon village, a hydroelectric plant and lines to carry the electricity nine miles to the mine. He also built a variety of structures at the mine, including a mill, magnetic separators, a furnace, trestle tramways, a 400-foot-long brick flue to trap dust and a 125-foot-tall brick chimney to carry off smelter fumes. He is estimated to have spent at least a million dollars on these improvements. Seems, oddly, to have changed the name of the Elizabeth Mining Company to Elizabeth Copper Company, then organized the Vermont Copper Company, an Arizona corporation, as its successor. (Note: The Anahma Realty Corporation, a corporation organized and existing in the State of New York, is also a Heckscher creation. Possibly was a holding company holding several of these smaller enterprises.)
1909, February	After a brief run in the winter of 1908-1909, Heckscher's 300-ton blast furnace is destroyed by explosion and fire. Another blast furnace, of 200 tons capacity, built, operates two weeks before main flue collapsed. Diamond drilling continues sporadically.
1917	The old magnetic separation plant remodeled into a flotation plant; a new smelter built, plant operated to end of First World War. In 1917 a 100-ton flotation plant, shortly increased to 200 tons; produced 300,000 pounds of copper in concentrate.
1919, May 1	Company closes. Company reported into receivership.
1920 April	The Vermont Copper Company reported to be preparing to do more extensive work in the near future.
1925	Mine and mill leased to The American Metal Company, of Vermont; which adds a 16-cell minerals-separation machine; operates about six months, mining 20,000 tons of ore and producing 1756 tons of 18 percent concentrate, then cancels its lease because of drop in copper prices.

Appendix A: Outline History of Elizabeth Mine, Strafford, Vermont (continued)

Date	Event
1928	National Copper Corporation incorporated, LeRoy M. Gross of New York City president. Also referred to as the Livingston Syndicate, Inc. S.A. Mewhirter, Manager. flotation mill remodeled and its capacity increased; large Marcy ball mill added and the coarse crushing plant redesigned. Twenty-year lease signed in January 1929 was taken by the Vermont Copper Corporation, a Delaware corporation with offices at 39 Broadway, New York City, but by the time the company modified the lease in December 1929, it had changed its name to National Copper Company; operates from April 1929 until June 1930, producing at the rate of 80 tons of copper per month; shuts down.
1928, November	Anahma Realty Corporation grants Theodore Gross three-month right to investigate the mine to assess its value with a view to leasing it for 20 years.
1929, January	Anahma Realty Corporation leases mine for 20 years to Gross's Vermont Copper Corporation, a Delaware corporation.
1929, December	Lease of January 1929 modified in view of lessee's plans to expend $10,000 in development and improvement of the mining property; lessee company has changed its name in the interim and is now the National Copper Company. Corporate seal has date of 1928. Operates from April 1929 to June 1930, with daily production of 350 tons of ore. Many improvements at mine and mill despite difficulties such as scarcity of experienced miners. Operations also hampered by such things as violent electrical storms and then finally ended by the Great Depression.
1942, September	Contract with U.S. Government announced. Copper now a crucial primary material of national defense. Government loan of $550,000 and a guarantee to purchase the product at a premium. At least 16,500,000 pounds of copper to be furnished the war program. Later would come road construction under Defense Highway Act of 1941; 40 new homes for workers and families constructed by Vermont War Production Board.
1942, April	Vermont Copper Company, Inc. organized with private capital. Elizabeth mine still owned by Anahma Realty Corporation at this time but purchased by Vermont Copper Company along with the Ely mine in Vershire and the Pike Hill mine in Corinth. Additional mineral rights were acquired in the 1950s, for a final total of about 8000 acres of Orange County land.
1943, spring	Production begins though mill does not process its first ore until October.
1943, 9 June	Company petitions to have the public highway through the valley of its land discontinued; granted by Orange County Court.
1946	Heckscher's chimney demolished as unsafe.
1954, June	Property purchased by Appalachian Sulphides, Inc., a corporation organized and existing under the laws of the State of Delaware and a wholly owned subsidiary of Nipissing Mines of Canada. Various attempts were made to convert the tailings into something of value: A process was successfully developed to produce iron by electrolytic refining but proved to be not cost-effective; for several years, 25,000 tons of pyrrhotite concentrate were shipped to Brown Paper Company in Berlin, New Hampshire, to make sulfur dioxide for use in paper-manufacturing.

Date	Event
1958, February	Mine is closed down. During this last period of operation, the mine was extended downward underground and northward as far as the Ompompanoosuc River and beyond; the northernmost open pit was deepened and the Number 2 open pit excavated (in the last years, from 1952). A vertical shaft and a new adit were opened to improve hauling of ore from the lower levels to the mill. Total production of ore close to 3 million tons of ore averaging 1.706 percent copper. About 91 percent of the copper was recovered into concentrate with 24 percent average copper content. the mill handled 800 tons per day under normal operating conditions, with peak handling over 1000 tons per day. Some 40 million pounds of copper was produced; the concentrate being shipped to Phelps Dodge smelter at Laurel Hill, Long Island. Peak employment was 220 workers from Strafford and 16 surrounding towns; annual payroll topped $1 million, sales peaked at over $3 million.
1961, June	Land and some personal property and fixtures sold by Appalachian Sulphides, Inc., to Leonard H. Cook.
1969, December	Leonard H. Cook sells several parcels of the former mine property, including 250 acres or more now owned by Theodore F. Zagaeski.

Some further notes on names:

It can be confusing that the name "Vermont Copper Company" was used by two separate groups at different periods, and also that a very similar name, Vermont Copper Mining Company, was used at the Ely Mine, the only instance here of both the word "Copper" and the word "Mining" in one and the same name.

Various other names also occurring in Strafford records relating to copper but not pertaining to the Copperas Hill or Elizabeth Mine site include, in no particular order: Orange, Gove, Hazelton, Kent lot, Green Mountain, Cornwall, Suffolk Copper Company, the Reynolds Mineral & Chemical Company.

Appendix B: Tables of Selected Surface Water Data from Previous Studies

Appendix C: Tables from the Elizabeth Mine Water Quality Summary, August 2000